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Solving the Mystery of Endless Life between Conodonts and Lampreys, Plus a Reason for Final Extinction of the Conodonts

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Abstract

New insight about extinct conodonts and their sister group, extant/prehistoric lampreys attempts to explain enigmatic patterns of their disappearance and survival, respectively. Conodonts and lampreys are very comparable to one another because: they both resembled eels in body plan while also being jawless and armorless; their mouths were used only for a "grasping" purpose; and they attacked their prey in parasitic fashion. Their mode of attacking was by latching onto another animal with their mouth while slowly suction-feeding on their victim's body fluids, but this advances a new revelation about them. While these particular fish slowly nourished upon their host-victims, the simple unity of multiple conodonts or lampreys and their host victim must have mimicked the tentacles/arms of a cephalopod and/or jellyfish. One reason why cephalopods and jellyfishes were and are successful throughout the Phanerozoic Eon, is due to their tentacles/arms representing a threat of entrapment and/or a venomous sting to other predators, thus discouraging would-be attacks. Hence, it is hypothesized here, that the ecological mimicry of tentacled animals by the combinatorial lineage of conodonts/lampreys helped them to survive throughout the entire Phanerozoic Eon. This uniquely signifies that their original jawless, armorless, body plan never evolved because it was already of optimal design, which promoted endless life between them.

Keywords: Jawless fishes; Parasite; Mimicry; Tentacles/arms; Paleoenvironment/environment

Introduction

Conodonts and lampreys

Two very similar animals, the extinct conodonts (Figure 1) (Phylum: *Chordata*; Superclass: *Agnatha*; Class: *Conodonta*) and their sister group, the lampreys (Figure 2) (Phylum: *Chordata*; Superclass: *Agnatha*; Class: *Petromyzontia*) [1-4] offer us clues which help us obtain a better understanding of their extinction and survival through the ages, respectively. A feasible survival strategy is hypothesized here to explain a conundrum which is the persistence of vulnerable-looking conodonts that ranged from the Cambrian Period to the early Lower Jurassic Epoch while the vulnerable-looking lampreys have survived since the Devonian Period.

Conodonts are ubiquitous, marine, photic-zone [5], jawless, armorless, worm-shaped to eel-shaped, large-eyed [6] fishes with a continuously-exposed oral cavity (open mouth) [7] and were active swimmers of the water column but were not bottom-dwellers [8] who ranged from 40 mm [1] up to 40 cm in length [9]. Lampreys only differ from conodonts in that they are found in both marine and non-marine waters while ranging up to ca. 1 m in length [10].

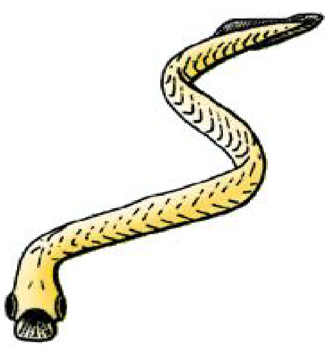

Figure 1: A diagrammatic, dorsal/oblique view of the extinct conodont animal whose oral cavity (mouth) was perpetually kept open since it was a jawless fish. A better view of a conodont's exposed oral cavity is illustrated in Figure 5. From Purnell et al. [7]. Reproduction through the courtesy of Wikipedia.

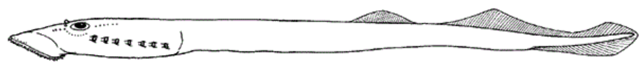

Figure 2: A diagrammatic, lateral view of a representative lamprey (*Mordacia lapicida* sp.). The continuously-opened buccal funnel (mouth) of this jawless fish (located at the anterior end of this animal) is illustrated in Figure 6. Reproduced through the courtesy of Guyana Zoologica journal.

Hagfish

Hagfish [11] (Phylum: *Chordata*; Class: Myxini), are not incorporated into this study for many reasons. Hagfish are eel-like, slime-producing, jawless marine fish, averaging .5 m to 1.25 m in length and are 'living fossils' since the extant hagfish retains its overall relict form dating back to the primitive hagfish, 300 Mya, particularly *Myxineidus* sp. [12]. It is dissimilar to the lamprey and conodont because it is an aphotic-zone, sluggish, bottom-dweller and nearly blind [13,14] along with the following characteristic: the hagfish's protective 'shield' is its capability of very quickly emitting a slime from out of its visible glands that clogs and disables the gills of predators while it rids itself of its own slime by easily tying itself into a knot [15,16]. The conodont and lamprey have no such self-protective agent as the hagfish since no evidence of this was found in the fossil record nor in

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extant lampreys. Furthermore, Janvier [2] places the conodonts into a sister group of lampreys but not into the sister group of hagfish. But the hagfish's protective 'shield' is a key reason why the hagfish survived from the Devonian up to the present time which will shed some light on a different subtle characteristic that helped the combinatorial lineages of the conodonts and lampreys to survive throughout the whole Phanerozic Eon, a theme discussed later in this study.

Methods

The writer bases the study on scientific data from: primary literature sources such as many, scholarly, peer-reviewed journal papers, monographs, etc.; and also photographic evidence from credible, websites. This was procured through a spectrum of sciential disciplines such as the biology, ecology, paleontology and historical geology of fish. Hence, the synthesis of the existing empirical data, observational evidence, and indirect evidence fostered a discussion of the study's two-fold thesis while generating novel insight and resolution towards a long-standing puzzle.

Parasitic Feeding

In addition to the resemblance of the conodonts to lampreys, there are other important similarities as well, including the conodonts' feeding-mechanism which incorporated s, m (both anterior) and p (posterior) elements (denticles) in its oral cavity: The set of elements (apparatus) was used for grasping and shearing [17,18] while Zhuralev [18] defined the grasping action as "holding onto prey". Their "grasping action" is very significant towards the feeding habit of conodonts, considering they were all jawless. It also invites a discussion about it and a very reasonable comparison. Renaud [10] characterized lampreys into two different categories: ectoparasitic and nonparasitic. He further described the parasitic type's mouth as containing teeth and a rasping organ (lingual laminae) for a hematophagous species while a flesh-feeding species feature teeth and a gouging organ (lingual laminae). They all utilize parasitic suction to attach onto their host victim (i.e., fish) while very slowly sucking out its nutrients for a prolonged period of time [10]. The end result of this parasitism is the gradual weakening and in many cases, ultimately the death of the host victim. In the latter case (death of the host victim), the lamprey is then classified as a predator, rather than as a parasite. This is correlated to Janvier [19] who concluded that conodonts developed suction-feeding while there is direct observation of modern lampreys orally attached to a host victim (Figures 3 and 4). The "grasping action" of conodonts is homologous to the ecological behavior of lampreys, as reported by Janvier [19] who paralleled the conodonts' elements to the grasping and rasping mouth of extant lampreys (Figures 5 and 6). This supports Gedik and Capkinoglu [20] and Gedik [21] who said that conodonts were parasitic animals because their elements (denticles) performed an anchoring and rasping function upon the host victim to cause it to bleed and extrude body fluids which were ingested by the conodonts. The parasitic feeding habit of the lampreys is even extended back to the middle Paleozoic of an Upper Devonian lamprey named *Priscomyzon* sp. as reported by Gess et al. [22]. Even though Purnell and Donoghue [23] was a proponent of the conodont's anterior (s and m) elements' capability of grasping prey, Goudimand et al. [24] modeled the action of these elements according to Purnell and Donoghue [23], and stated they were able to tear off the tissue of prey while also saying it was adverse to parasitic feeding. Conversely, the advocation of the present study is evidenced by Dzik [25] and Scholle and Ulmer-Scholle [26] who pointed out that all elements were not embedded into bone, but instead, into the soft tissue of the conodonts' mouths (as do the

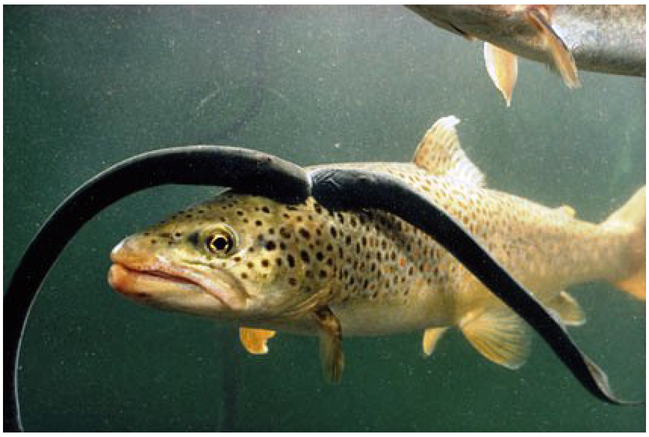

Figure 3: Even though they are jawless, a photograph epitomizes extant lampreys "grasping" by rooting themselves into a fish within the Great Lakes, USA, and Canada. This same scenario was most likely repeated an infinite number of times by multiple conodonts swarming and attaching themselves onto their host victim while predators kept their safe distance from them due to the threat of ecological, tentacle/arm, mimicry. In the inevitable event of a large number of conodonts festooned upon a host victim, the threat of simulated tentacles/arms was magnified to a potential predator because cephalopods and jellyfishes have many tentacles/arms themselves. Photograph is accredited to James L. Amos of National Geographic. Permission to use is granted by National Geographic Creative.

Figure 4: A photographic example of more than two sea lampreys attached to a host victim, demonstrating the fact that lampreys do not only attack as couplets as in Figure 3. In this case, the host victim is a basking shark. Permission to use granted by SeaPics.com

lampreys), which implies the ability of the s and m elements to truncate tissue off the body of prey is in question. This is supported by Jones et al. [27] who doubted the conodonts' ability to bite and instead, only favored the ability to puncture, while emphasizing the jawless factor.

Moreover, microware or edge damage found upon the posterior (p) elements, located in the oropharynx of conodonts (Figure 5), was attributed towards crushing of food by those elements before swallowing [28]. Microwear there would be expected in a hypothesized parasitic lifestyle for conodonts due to small hard parts (i.e., fish scales) of the host victim being physically granulated while its body fluids were sucked out so that safe swallowing is accomplished. This is comparable to the posterior-rooted, rasping or gouging, toothed tongue (lingual laminae) of the lamprey (Figure 6) physically abrading small hard parts (i.e., fish scales) of the host victim as the lamprey is draining its host victim of its body fluids before swallowing [10,29]. To sum up, this study emphasizes that the s and m elements (denticles) of a conodont's

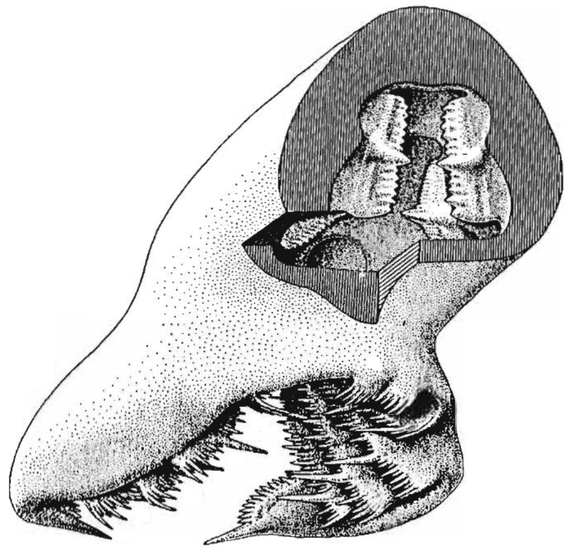

Figure 5: A diagrammatic, anteroposterior view of an oral cavity (mouth) and elements (denticles) of a representative conodont animal (*Pandorinellina* sp.), who was, of course, jawless. The epidermal s elements are lined up in rows while a pair of epidermal m elements border the front-row denticles. Further at depth within the mouth (open section of illustration) are the p elements of the pharyngeal area. Note that all elements are embedded only in soft tissue. All together, these elements were correlated by Janvier [19] to the same functional purpose towards the parasitic feeding habit of a lamprey. Reproduced through the courtesy of Acta Palaeontologica Polonica journal [25].

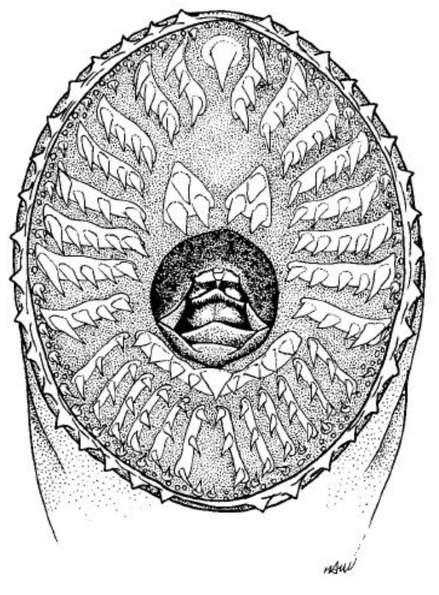

Figure 6: A diagrammatic, anterior view of the buccal funnel (mouth) belonging to a representative lamprey (*Mordacia lapicida* sp.), who is, of course, jawless. Upon the mouth, are epidermal teeth lined up in rows, while at depth within the mouth, is a center composed of transverse and longitudinal lingual laminae. Note that all teeth are embedded only in soft tissue. In general, both these teeth and laminae structures were correlated by Janvier [19] to serve the same functional purpose towards the feeding habit of the conodont animal. Reproduced through the courtesy of Guyana Zoologica journal.

anterior part of the mouth was not used in biting off the tissue of prey, but instead, were used for only grasping, comparable to the lamprey's teeth in the anterior part of its mouth, performing that same action, while both types of animals used their deep-seated, denticles or teeth to physically pulverize small hard parts besides draining the body fluids of their host victims, all within a framework of parasitic feeding.

An obvious advantage to parasitic feeding upon nektonic animals

There is an obvious advantage to parasitic feeding upon swimmers relative to longevity of the parasite besides conserving energy since it is not doing the work of actively swimming. Parasites attached to either self-protected animals (i.e., predators) or very large animals (Figure 4) are protected by them because other animals are less inclined to prey upon the host victim. But although it seems parasitic feeding upon the smaller and non-predatory swimmers would not contribute towards the longevity of the parasite, a closer look at this type of relationship may reveal the opposite of what is expected. This is explored in the upcoming discussion.

Palaeoecological/Ecological Mimicry as a Protective Mechanism towards Long-term Survival

The mystery of endless life regarding the combinatorial lineage of the jawless, armorless, vulnerable-looking conodonts and lampreys throughout the Phanerozoic Eon (spanning the Cambrian to the present) has never been accounted for in the literature. It is reasonably hypothesized here that the unity of parasitic conodonts/lampreys and a host victim, in a confluent way, created the illusion of a tentacled animal such as the ubiquitous cephalopod (Class: Cephalopoda) or jellyfish (Phylum: *Cnidaria*) to potential predators, thus, discouraging a predator from attacking. Avoidance by predators is a visceral or instinctive reaction because many jellyfish are venomous while all octopuses, cuttlefish, and some squid (Class: Cephalopoda) are venomous, being derived from a common, ancient venomous ancestor [30]. Also, avoidance is exacerbated by the fact that cephalopods were the dominant marine predator at least throughout the Paleozoic Era [31]. Illusion is unintentionally fabricated by the two tentacles of a cephalopod (squid)resembling the conodont's or lamprey's very slender body plan while the fan-shape ends of their tentacles are roughly morphologically similar to the posterior fin rays of those fish when comparing with Figure 7 to Figures 1-3. Likewise, the morphology of a pedalium and tentacle belonging to a jellyfish resembles the morphology of the dorsal view of the lamprey's head and body respectively, when comparing with Figure 8 to Figure 3. Thus, mimicry is just a matter of cognitive misinterpretation by the potential predator. The known parasitic, feeding habit of lampreys and the likewise presumed parasitic feeding habit of the conodonts must have coincidently and conceivably posed as an illusory threat to predators which is equated as a protective 'shield'. Cephalopods and jellyfishes have been successful, ubiquitous animals throughout the Phanerozoic Eon while conodonts coexisted with them up until the time of the very early Lower Jurassic [32] and lampreys coexisting with them since the Devonian. Fossilized proof of paleo-ecological mimicry by conodonts is not known but an indication of it is suspected in this study when we interpret fossilized evidence of conodonts occurring more frequently in cephalopod-limestone beds than any other taxon during a mass extinction event of the end-Devonian in Germany [33]. This significant association at least equates to a correlative accompaniment resulting in paleo-ecological commensalism within the paleo-community which promoted an aggrandizement of the conodont population.

The general category of ecological mimicry referred to in this study is known as Batesian mimicry which is defined as an unprotected species of animals resembling a protected species for the sake of disguise [34]. Just as important, is Rothschild's [35] definition of mimicry who

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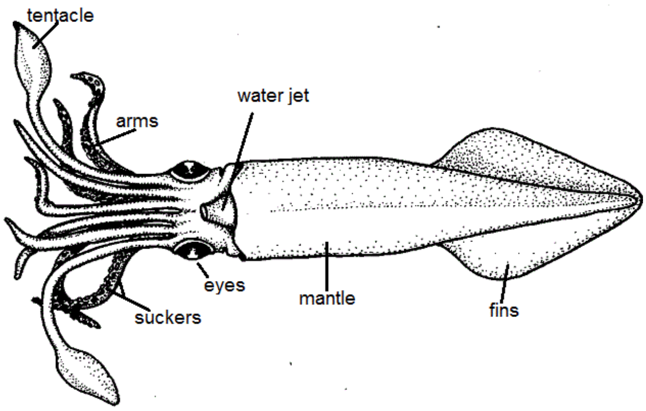

Figure 7: Diagram of a cephalopod (in this case, a squid). Note the fan-shaped ends of the two tentacles roughly resembling the posterior fins of either lampreys or conodonts. As opposed to the arms of the cephalopod, the fan-shaped tentacles do the job of extending and reaching out to grasp prey. Predators would have a difficult time deciphering these type tentacles from, let's say, lampreys attached to a fish as in Figure 3 of this study, which should motivate predators to at least keep a safe distance away from the lampreys during their prolonged time of parasitic feeding. Reproduced through the courtesy of Biologycorner.com (Creative Commons Attribution 3.0).

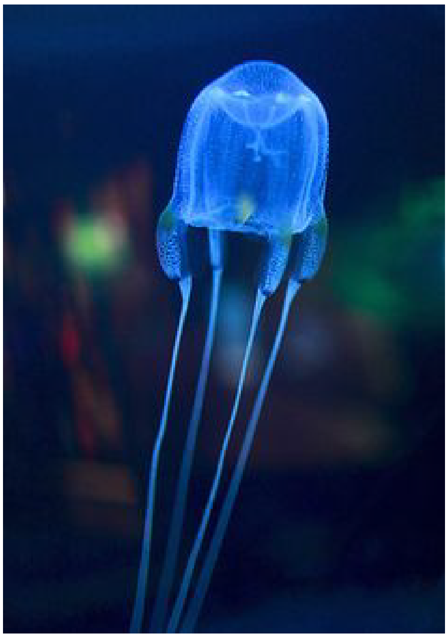

Figure 8: Photograph of a jellyfish (*Phylum: Cnidaria*; Class: Cubozoa). Note how an individual padalium (which are each of the individual four oval forms attached to the side-bottom of the bell-shaped body) of the jellyfish morphologically resembles the head of a conodont/lamprey while an individual tentacle is attached to each of the padaliums, resembling the body of a conodont/lamprey. Photograph courtesy of Two Oceans Aquarium.

said it is an animal emulating another animal or its components. It should be obvious to any observer that mimicry in this study is the type that occurs without any deliberate attempt by the mimicker to imitate another. Another related type is paleoecological mimicry which is a strategem used by marine animals of the past while Kacha and Petr [36] presented an overview of this. For example, *Platyceras* (Class: Gastropoda) is a Paleozoic gastropod that featured spinose ornaments on its shell which altogether mimicked crinoids (Kingdom: Animalia; Phylum: Echinodermata; Subphylum: Crinozoa) [37]. Furthermore, a kleptoparasitic feeding strategy was employed by *Platyceras* through extraction of unprocessed food from the anus of the crinoids before the food could be processed into pellets [38]. The study of the preceding fossil by Bowsher [39] promotes an axiom about a parasite's lifetime dependency since that investigator correlated the immediate aftermath of the crinoids' extermination to the extermination of these type gastropods at that same time. The reverse of that axiom would then be true of the ongoing existence of the cephalopods and jellyfish with the conodonts and lampreys throughout the Phanerozoic Eon. This becomes even more evident later in this study.

The endurance of the jawless, armorless and vulnerable-looking conodonts from the Cambrian through the early Lower Jurassic time span is a phenomenon since virtually all other ancient, jawless fishes, whether armored or not, became either extinct during the Devonian Period, or evolved into jawed fishes, while the conodonts consistently retained and maintained their relict jawless, body plan during the Paleozoic Era and into the Mesozoic Era. This is simply reflected by the fossilized remains of a conodont's soft-tissue anatomy found in the Granton Shrimp bed of Mississippian age [40] and at other locations such as South Africa in marine bedrock of Ordovician age [9]. Even though only elements (teeth) of conodonts were found to prove the existence of the conodont animal during the Mesozoic Era, the inference of the conodonts further retaining and maintaining their relict, jawless body plan into the Mesozoic, is plausible due to the fact that their relatives, the lampreys, consistently retained and maintained their relict, jawless body plan biostratigraphically from at least the Devonian up through the present time [10,22,41,42]. Thus, the above allows us to postulate that palaeoecological mimicry naturally and pivotally inhibited the evolution of the relict body plan of conodonts/lampreys (i.e., not evolving into jawed fishes) due to their ongoing success at surviving. It should be noted here that even though the ecological mimicry by the conodonts/lampreys was not an exact, optical duplication of a cephalopod or jellyfish, it did however, convey the image of tentacles/arms belonging to a cephalopod/jellyfish, which again, logically had to deceptively and starkly signal a "red flag" to a predator, since the tentacles/arms represented a threat of entrapment or a venomous sting. This strictly adheres to Rothchild's [35] definition of mimicry whereas one animal emulates another animal's components. A reasonable corollary to this is the event of when many multiple numbers of conodonts or lampreys attached themselves to one host-victim which resulted in a magnification of the threat of tentacles/arms since cephalopods/jellyfish have many tentacles/arms themselves. The confluence of the conodont/lamprey body plan and parasitic attachment not only equates to mimicry and hence, a protective shield for these animals but it also implies that their jawless, armorless, very slender, body-form was already of optimal design, helping them to move unscathed throughout the entire time of the Phanerozoic Eon, while time stood still for them during that eon of time since their body plan never evolved.

The theme of this study is applicable to a riddle entertained by Palmer [43] who asked the question of why organisms evolved shells during the Cambrian, even though predators at that time were jawless. The answer is obvious if we take into account the parasitic nature of the conodonts which was an integral part of the ecological seascape at that time. The other jawless, armorless fishes during the Cambrian [44] most probably served as the host-victims of the conodonts during the same time. With that in mind, it is further likely that this provided the stimulus towards the rise of the first ossified (armored) jawless fish (ostracoderm) during the Ordovician while the conodonts remained armorless.

Anyone who is an opponent of the mimicry hypothesis would then have to provide an adequate explanation demystifying the actual mechanism that propelled the survival of the combinatorial lineage of the jawless, armorless and vulnerable-looking conodonts/lampreys throughout the whole Phanerozoic Eon.

Events Leading Up Towards Survival and Near Extermination of the Conodonts

The disappearance of the last species of conodont (*Neohindeodella detrei* sp.) is correlated to a large, rapid drop in sea level during the Hettangian Stage of the Lower Jurassic Epoch as reported by Palfy et al. [32]. Vail et al. [45] illustrated this very same swift-sealevel drop globally during the Lower Jurassic. However, a paradox clouds the issue of the conodonts' overall gradual extinction when we consider the latter half of the Permian Period which saw two, separate, mass extinction events. This is because the end-Guadalupian Stage (260 Mya) of the Permian experienced a large regression of the sea, almost as paramount as the Hettangian sea regression while many conodonts and other fishes survived this first mass extinction. A resolution to this pattern is by considering two factors: Hallam and Wignall [46] noticed that only low-latitude marine environments were mainly affected while higher-latitude marine environments were not affected during the end-Guadalupian; and Hallam and Wignall [47] pointed out that primarily benthic organisms were affected while nektonic organisms (such as the conodonts and other fishes) were largely unaffected during the end-Guadalupian crisis. Thus, the free swimming mobility of the conodonts/fishes likely allowed them to migrate to cooler oceanic environments while the sedentary, benthic organisms were forced to face whatever environmental stress that caused the end-Guadalupian extinction as suggested by Sengor and Atayman [48]. Then, a second mass extinction occurred during the time of the end-Permian (251 Mya) but Hallam and Wignall [47] emphasized that at that time, a reversal happened when there was a transgression of the seas, culminating in a high sea level stand. They also reported the net result of this was that many of the conodonts and other fishes evaded the second extinction since they survived into the Triassic Period.

The ongoing transgression of the sea during the Triassic Period then leveled off at approximately mid-Triassic time followed by a complexity arising at end-Triassic time. This particular intricacy took shape when a major regression of the sea occurred but was interrupted by a transgression of an epicontinental sea into northwestern Europe which reduced marine salinity, resulting in a very great depopulation and decline of all conodonts at the end-Triassic [49]. The reason for the near extermination of all conodonts at that time is valid because the rock record of all conodonts indicates that they were strictly stenohaline in nature as confirmed by DeRenzi et al. [49].

Palaeoenvironmental/Environmental Diversity towards Survival of Lampreys and Final Extinction of the Conodonts

We can calculate an underlying reason for why the fast sea level drop completely annihilated the last of the conodonts (*Neohindeodella detrei* sp.) during the Henntagian Stage of the early Lower Jurassic Epoch if we correlate environmental diversification patterns of prehistoric and extant lampreys. Conodont fossils are found only in lithostratigraphic, marine bedrock while prehistoric lampreys are lithostratigraphically more eurytopic, found in a wide range of paleo-habitats: an Upper Devonian Epoch lithified, estuarine deposit in Africa [22]; a Pennsylvanian Epoch marine faces of a paleo-delta in Illinois [41]; and a Lower Cretaceous Epoch lithified, freshwater deposit in China [42]. Although the lampreys were contemporaneous with the conodonts during the Upper Devonian, the lampreys had already demonstrated adaptability to a wide range of mixed salinities at that time. This was followed by the lampreys fully adapting to fresh water no later than the Lower Cretaceous. Today, extant lampreys are euryhaline, found in: open-marine waters; brackish waters; freshwater lakes [50] (i.e., the Great Lakes of the USA and Canada); and the arctic aquatic habitat (*Lethenteron camtschaticum* sp.). Thus, the implication here is that the environmentally-diversified lampreys dodged any stressful marine condition during the Hettangian Stage of the Lower Jurassic by demonstrably finding refuge in the estuarine environment and inferentially finding refuge in freshwater environments. They would have accessed the latter environment by simply swimming into tributaries that led to freshwater environments. There is evidence of altered, biotic conditions occurring in the past, which caused stresses in paleo-marine environments. For instance, the initial, new arrival of increasing amounts of abundant calcareous, phyto-nannoplankton algae (*Coccolithus* genus) (Kingdom: *Chromalveolata*; Phylum: Haptophyta; Class: Prymnesiophyceae) during the Lower Jurassic [26,51] can be assigned as a pestilence of the conodonts and lampreys in the seas. But it was inevitable that the very last species of the conodonts (*Neohindeodella detrei* sp.) was coincidently extirpated at that same time because they were apparently only static or incapable of shifting from their habitat. In contrast, the lampreys swam into either estuaries or into tributaries that led to freshwater environments. Alternatively, this could have been just a simple case of the lampreys swimming towards higher latitudes of the marine realm where calcareous microplankton are displaced by siliceous microplankton in cold waters [26] while the vastly depleted conodonts (only *Neohindeodella detrei* sp. remained) may have been intolerable of low-temperature waters after initially migrating there. But if the last reason was completely true, it would seemingly contradict the fact of the wholesale number of species of conodonts and other fish who were able to acclimate themselves to cooler waters for the sake of survivorship during the end-Guadalupian (Permian) crisis, as previously discussed. So, this diminishes the chance of low marine temperatures as a reason towards eradification of the last species of the conodonts (*Neohindeodella detrei* sp.). But when we proclaim the very fast sealevel drop itself as the cause of extinction for *Neohindeodella detrei* due to competition resulting from minimization of its environmental space, then the same rationale of the lampreys' exodus into estuaries or freshwater environments still applies, while ecological inflexibility (stasis) and ultimate demise still applies here to the last species of the conodonts.

The above noted adaptability to different paleoenvironments by the lampreys is paralleled by Laporte's [52] paleoecological example. He concluded about pond-dwelling amphibians (*Diplocaulus* sp. and *Trimerorhachis* sp.) flourishing within their own Lower Permian paleoenvironment until the advent of a predatory shark (*Xenacanthus* sp.) which motivated these amphibians to relocate into a high-energy stream habitat, where they withstood competition by the shark.

The preceding, overall discussion raises a question: if ecological mimicry promoted the lives of conodonts/lampreys, then how useful was the mimicry to the lampreys in fresh water where there are seemingly neither cephalopods nor jellyfish? Surprisingly and factually, there happens to be extant, ubiquitous, small, freshwater jellyfish with tentacles such as *Craspedacusta* sp. and *Limnocnida* sp. (Phylum: Cnidaria; Class: Hydrozoa) but, a better answer to that question, is the lampreys' adaptability to the sea besides to the fresh water realm. In other words, if mimicry is or was not useful for the lampreys in fresh water because of a lack of cephalopods there, leaving the lampreys vulnerable to predators, then their generalized retreat back into the seas [10,53] is their outlet where the mimicry does help them to survive due to the many numbers of cephalopods and jellyfish existing there.

Comparison to Other Successful Nektonic Animals in Perpetual Existence throughout the Phanerozoic Eon

The successful endurance of conodonts from the Cambrian Period up to the Lower Jurassic and even much longer for the related lamprey can be compared to other successful marine nektonic, animal-life endurance. For instance, the modern, horseshoe crab (*Limulus* sp.) and its ancestors (Order: Xiphosurida; Suborder: Synziphosurida) biostratigraphically survived from the Cambrian (i.e., out-group taxon *Paleomerus* sp.) [54,55] up to the present time (i.e., in-group taxon *Limulus* sp.) [56]. The horseshoe crab is both nektonic and benthic (nektobenthic) [56] and their survivorship through the ages depended on two main, environmental controls which are and were tolerance of various ranges of salinity (mostly euryhaline) and to cool temperatures [57], plus their protective 'shield' or body armor [57]. In comparison to that, as discussed earlier, even though many conodont species survived through the end-Guadalupian extinction of the Permian Period because of their tolerance of cool or cold waters [48], the last species of the conodonts (*Neohindeodella detrei* sp.) ultimately became extinct during the Hettagian Stage of the Lower Jurassic most probably because of their unadaptiveness to either: the new high concentration of calcareous phyto-nannoplanktic algae; fast sea level fall; or the least possible reason which was low marine temperature due to a probable preclusion as discussed earlier. In contrast, their sister group, the lampreys, were able to escape from the previously-mentioned conditions, by swimming into: freshwater and a range of euryhaline aquatic habitats, or being able to tolerate cold marine temperatures. This perpetuated their own survivorship from the Devonian to the present. Finally, failure to conform to one of the above environmental controls by the horseshoe crabs' cousin, the trilobites, which were another arthropod clade, led to its extinction just because it was intolerant of cool water during the end-Permian [48,56]. This last fact completes the overall analogy of the survivorship throughout the Phanerozoic Eon accredited to the conodonts/lampreys and horseshoe crabs, which bolsters an axiom, or at the least, a rule of thumb about it.

Interestingly enough, a simple hierarchy of successful, marine, animal-life endurance through the ages is measured, placing the jellyfish at the apex of the chart. This is because its original body plan was optimal due to it retaining its protective 'shield' (stingers), soft tissue, mobility, tolerability to temperatures and salinity while it always remained shell-less. It is followed by the other marine animals discussed in this study such as the combinatorial lineage of the condonts/lampreys, cephalopods, and horseshoe crabs.

Future Research

Future research concerning the study's hypothesis may involve simple testing of it. One conceivable test is to emplace a fish with a multiple number of lampreys attached to the fish inside a very large, spacious, transparent, sea aquarium that already has many same-sized non-predatory fish but only a very small amount of same-sized, predatory fish. Then simple observations would have to be made about whether or not, the predatory fish attack the non-predatory fish or the lamprey-attached fish. Testing would only be fair if the predatory fish had already lived and survived beforehand in a community with cephalopods and jellyfish for a lengthy amount of time before being emplaced in the above sea aquarium. All together however, the practicality of the above may be easier said than done, though not wholly impossible to achieve.

Conclusion

Virtually all jawless fishes either became extinct during the Devonian Period, or evolved into jawed fishes, while the combinatorial lineages of the conodonts and lampreys retained and maintained their relict jawless, armorless, body plan, biostratigraphically from the Cambrian Period up until the present time, and so, a novel and valid explanation for this phenomena or enigma of ongoing endurance is offered here. This study adds up all the unique, individual points of collective, circumstantial evidence about palaeoecological mimicry in the case of the conodonts, since it is rare for the paleontologist to garner fossilized evidence of any type of mimicry although there is the recognition or perception of Schulke's [33] discovery in this study as being fossilized evidence of at least paleoecological commensalism between wholesale, conodont-mimicry and cephalopods. Ecological mimicry of tentacles/arms belonging to the long-successful cephalopods and jellyfishes by the conodonts/lampreys is reasonably hypothesized here as a long-term survival mechanism through the simple observation of the similar-looking, extant lampreys fulfilling their eating habits by attaching themselves to another animal which pivotally gave the illusion of tentacles/arms. This would have both alarmed and discouraged potential predators from attacking while helping to cement the survival of both the conodonts from Cambrian time up until the early Lower Jurassic and the lampreys from Devonian time up to the present time since the tentacles/arms of the successful cephalopods/jellyfishes induced this same reaction by other potential predatory animals consistently throughout the Phanerozoic Eon. Thus, now it is easily comprehensible about the relict body plan of the jawless, armorless conodonts and lampreys remaining unchanged throughout the Phanerozic Eon, since the confluence of their body plan and lifetime parasitic feeding-habit was of optimal design that mimicked tentacles/arms of the cephalopods and/or jellyfish, resulting in their 'protective shield'.

Lampreys varied in their ability to survive the extinctions that exterminated conodonts because they were environmentally resourceful. It is suggested here that the very last species of the conodonts (*Neohindeodella detrei* sp.) became extinct during the Hettangian Stage of the Lower Jurassic because it was either: unadaptable to estuarine or freshwater environments; or the lesser likelihood of not being able to tolerate cold-water conditions. Situations relating to that are when those conodonts attempted escaping or migrating away from: a toxic event such as the timely, new arrival of a calcareous microplankton algae bloom; or a calamitous event such as the rapid, exorbitant, sealevel fall which increased competition due to a minimization of their environmental space. Inversely, the lampreys demonstrated environmental flexibility by ably escaping into either: estuaries; or freshwater habitats; or even the low-temperature marine environment. The preceding is evidenced by fossils of prehistoric lampreys already present in the estuarine environment during the Devonian and by the inferential evidence of their adaptation to the freshwater environment if we interpolate the fossilized lamprey, freshwater deposit of the Lower Cretaceous Epoch into this equation. The aforementioned interpretations and facts are based in part on the fact that extant lampreys are found in a wide range of environments such as marine, estuarine, freshwater and arctic habitats. Thus, the main reason for the extinction of the last lineage of the conodonts is that they were simply not as paleoenvironmentally adaptable as the lampreys.

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